

Telehealth as a strategy to build outpatient care resilience during extreme weather

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Abstract

Extreme weather events are becoming more frequent and severe, disrupting outpatient care and endangering the health of patients with chronic illness and social vulnerability. Telehealth has the potential to help health systems build resilience during extreme weather, but evidence linking telehealth strategies to specific vulnerabilities and impacts remains fragmented. We conducted a scoping review of 14 studies describing telehealth use during extreme weather events. We mapped telehealth strategies to the system- and patient-level vulnerabilities and impacts they addressed, including chronic disease management, medication access, acute needs triage, and reaching displaced or homebound patients. In every study, telehealth was repurposed from existing infrastructure rather than built for disaster response, functioning as adaptive infrastructure. This mapping identifies actionable pathways for health systems to build resilience in outpatient care to mitigate health risks posed by extreme weather and highlights purpose-built disaster telehealth, integrated into formal preparedness planning, as a significant unmet need.

Introduction

Extreme weather events are increasing in frequency and severity globally¹, with growing consequences for health systems and patient care². Extreme weather has been associated with emergency department surges, disruptions in outpatient care, and increased mortality attributable not only to direct injury but also to interruptions in ongoing medical care^{3,4}.

Extreme weather affects health through multiple pathways: direct injury and environmental exposures, exacerbation of chronic conditions when care or medications are disrupted⁵, and delayed diagnosis or treatment for new conditions when practices close or become unreachable^{6,7}. The adverse impacts disproportionately affect patients managing chronic conditions and those in areas with limited access to care^{4,7,8}.

As weather-related hazards intensify, health systems are called to build resilience: to prepare for and adapt to weather disruptions while sustaining access to care⁹. Continuity of outpatient care can particularly be supported by telehealth through telephone and video visits and remote clinical workflows when physical infrastructure is compromised or travel is constrained¹⁰. However, telehealth lacks systematic integration into both disaster preparedness guidance and durable U.S. healthcare policy^{11,12}.

Disaster preparedness literature distinguishes between vulnerabilities (susceptibility to disaster consequences) and impacts (resulting experiences and outcomes) as components of risk^{13,14}. Although vulnerabilities and impacts of extreme weather on health risk are documented^{15,16}, evidence of telehealth's effectiveness in addressing these domains related to outpatient care disruptions has not been systematically synthesized.

We conducted a scoping review of telehealth use in outpatient settings during extreme weather events to characterize how telehealth has been used to maintain outpatient care access and to identify opportunities to align telehealth strategies with specific sources of population health risk.

Results

Search results and study characteristics

Of 1,145 records retrieved, 805 unique records remained after deduplication and underwent screening; 14 met criteria for inclusion. Figure 1 summarizes the study selection process.

Table 1 lists the included studies. Study designs varied, including three case reports, three cross-sectional studies, three cohort studies, two quasi-experimental studies, two mixed-methods studies, and one systematic review. Studies were largely conducted in the United States, with nine studies in the Gulf Coast and U.S. Southeast, two in California, and one in New York. Additionally, one took place in Japan, and the systematic review¹⁷ also included Australia and the South Pacific. Eleven of the 14 studies included hurricanes, 4 included wildfires, 3 included floods, and 1 included an ice/snowstorm. The study populations ranged markedly in size, from 194 to 3,700,000 patients or encounters.

Table 1
Characteristics of Included Studies

Study	Study Design	Health Care Setting/Location	Extreme Weather Event	Scope of Patients (or Visits, if specified)	Telehealth technologies and strategies
Vo 2010 ¹⁸	Case report	Academic health system, Texas, USA	Flood, hurricane	Single facility, 63,000	Phone visits, EHR access, system networks, and telehealth protocols
Radcliff 2018 ¹⁹	Cohort	Government health system, Gulf Coast, USA	Hurricane	Regional, 254,514	Phone visits
Uscher-Pines 2018 ²⁰	Cross-sectional	Private health system (DTC telemedicine), Gulf Coast, USA	Hurricane	Regional, 2,057	DTC/tele-urgent care, system networks, video visits
Der-Martirosian 2019 ²¹	Mixed methods (quantitative and qualitative)	Government health system, New York and New Jersey, USA	Hurricane	Single facility, 47,107	DTC/tele-urgent care, phone visits, system networks
Der-Martirosian 2020 ²²	Cohort	Government health system, Texas, USA	Hurricane	Single facility, 29,829	Home telehealth, phone visits, system networks
Der-Martirosian 2020 ²³	Case report	Government health system, Texas, Florida, and Puerto Rico, USA	Hurricanes	Regional, 181,451	Home telehealth, phone visits
Grover 2020 ²⁴	Cross-sectional	Government health system and private health system (DTC telemedicine), North Carolina, USA	Hurricane	Regional, 194 encounters	DTC/tele-urgent care, shelter telemedicine
Acronyms: DTC = direct-to-consumer, EHR = electronic health record					
Telehealth strategies and their targets					

Study	Study Design	Health Care Setting/Location	Extreme Weather Event	Scope of Patients (or Visits, if specified)	Telehealth technologies and strategies
Baek 2021 ²⁵	Mixed methods (quantitative and qualitative)	Private health system, Texas, USA	Hurricane	Regional, 557,024	EHR access, patient portal, phone visits
Friedman 2022 ²⁶	Observational quasi-experimental	Private health system, California, USA	Wildfire	Regional, 108,113	DTC/tele-urgent care, phone visits
Khairat 2022 ²⁷	Cross-sectional	Academic health system, North Carolina, USA	Hurricane	Regional, 10,056 visits	DTC/tele-urgent care, phone visits, video visits
Miyatake 2022 ²⁸	Case report	Private health system, Fukui City, Japan	Ice/snowstorm	Single facility, 294	DTC/tele-urgent care, phone visits, telehealth strategy
Lokmic-Tomkins 2023 ¹⁷	Systematic review	Healthcare settings not described; U.S. Gulf Coast, California, Australia, Timor-Leste, Pakistan	Flood, hurricane, wildfire	Multiple, Not described	DTC/tele-urgent care, EHR access, mobile apps, wearables
Casey 2025 ²⁹	Cohort	Private health system, California, USA	Wildfire	Regional, 3,700,000	Phone visits, video visits
Ramachandran 2025 ³⁰	Observational quasi-experimental	Government health system, Gulf Coast, USA	Hurricanes	Regional, 517,247 visits	Phone visits, video visits
Acronyms: DTC = direct-to-consumer, EHR = electronic health record					
Telehealth strategies and their targets					

We identified eleven telehealth technologies and strategies (Table 2) used to address system- and individual-patient vulnerabilities and impacts. Technologies enabled both synchronous and asynchronous interactions between the healthcare system and patients. Synchronous and direct interactions between healthcare providers and patients occurred through phone visits, video visits, direct-to-consumer (DTC)/tele-urgent care, and shelter telemedicine. Asynchronous or indirect care was mediated through patient portals, mobile apps, electronic health record (EHR) access, remote

monitoring, and home telehealth. At the healthcare system level, the review identified systems communication networks and telehealth strategies.

Table 2
Telehealth technologies and strategies identified in the review

Technology / Strategy	Definition
<i>Synchronous technologies</i>	
Direct-to-consumer (DTC) / tele-urgent care	On-demand, direct-to-consumer virtual urgent care for low-acuity needs, often via commercial platforms.
Electronic health record (EHR) access	Remote access to the electronic health record to support care continuity during disruption.
Home telehealth	Structured program delivering telehealth and/or monitoring to patients in the home (VA Home Telehealth in the included VA studies) with frequent provider review and structured care plan.
Phone visit	Real-time clinical care delivered by telephone (audio only).
Shelter telemedicine	Telemedicine services provided to evacuees at disaster/evacuation shelters; in this review delivered by web application on a tablet.
Video visit	Real-time clinical care delivered by two-way audio-video.
<i>Asynchronous technologies</i>	
Mobile apps	Smartphone or tablet health applications supporting health information or care delivery.
Patient portal	Secure online platform for asynchronous patient–provider messaging and access to records/results.
Wearables	Wearable devices that can track or monitor user data or provide tailored alerts.
<i>Systems/Strategies</i>	
System networks	Inter-facility or regional telehealth communication networks, built-in fault tolerance, and cross-state-line capacity.
Telehealth strategy	Integration of telehealth with normal services.

Vulnerabilities characterized at the system level included healthcare system capacity and infrastructure design. At the patient level, we identified age-related and socioeconomic vulnerabilities; a digital divide stemming from access barriers, limited English proficiency, and inexperience with telehealth technology; geographic barriers to healthcare access; medical complexity; and social isolation. All of these were identified as vulnerabilities that telehealth could possibly address and potentially mitigate.

System impacts included care continuity and appointment disruptions, primary care capacity loss, staffing shortages, medication impacts, facility and clinic closures, emergency medical services

overwhelm, healthcare system demand, and infrastructure failure. Impacts on patients included acute medical needs, chronic disease exacerbations, care continuity disruption, medication impacts, and mental health impacts.

We identified 120 telehealth–vulnerability/impact pairings across the 14 studies; their frequencies are shown in Fig. 2 and detailed in Supplementary Table 1. Phone visits were the most frequently documented telehealth intervention, followed by DTC/tele-urgent care and patient portal messaging. Video visits, shelter telemedicine, and system networks were documented less often, and EHR access, remote monitoring, and mobile applications were each rarely documented. Synchronous technologies accounted for most pairings. Few pairings addressed system-level vulnerabilities; the remainder were distributed across system impacts and individual patient vulnerabilities and impacts.

Example deployments

The following are examples of telehealth use identified in the review, along with how various technologies and strategies addressed vulnerabilities and impacts.

Phone visits and home telehealth played a key role in sustaining care for patients of a home care clinic in the February 2018 snowstorm in Fukui City, Japan²⁸. Although the normally scheduled in-person home visits were limited by the heavy snowfall, by using phone visits, the clinic was able to triage limited in-person visits or transfer to emergency services as needed. Phone visits enabled monitoring of stable patients, medication refills, and rescheduling of in-person visits. Phone visits also played a primary role in the 2017 Tubbs fire in Northern California²⁶, where they were found to be more effective than video visits during infrastructure failures that limited broadband connectivity. Phone visits were also found to be more equitable, as all patients had access to free phone appointments regardless of insurance. Patient familiarity with telehealth, via prior phone visits before the fire, was associated with a lower risk of post-fire emergency room or hospital utilization, and post-fire phone visits were commonly used by the telehealth-familiar patient group.

During Hurricanes Harvey and Irma, a DTC/tele-urgent care provider offered telemedicine services to patients via free synchronous video visits that were arranged through a mobile app²⁰. This technology addressed healthcare system capacity vulnerabilities and staffing shortages when local providers were displaced by offering a nationwide workforce to meet visit demand, facilitated by regulatory waivers for out-of-state doctors. The DTC/tele-urgent care provided continuity of care when facilities and clinics closed, making up for the loss of primary care capacity, and through triage, was able to minimize ED/EMS overwhelm. The DTC providers addressed acute medical issues including respiratory illness, skin problems, and injuries, as well as chronic disease management and medication refills.

The health system patient portal was an important tool when Hurricane Harvey hit the Houston, Texas area in 2017²⁵. The patient portal supported continuity of care through asynchronous communication for medical advice on acute needs (including injuries, floodwater exposure, post-surgical concerns, and obstetric concerns), management of chronic conditions, and medication-related requests (new

prescription requests, refills, and replacements). The portal was also useful for automated rescheduling of appointments due to clinic closures and delays. Providers were also able to perform targeted outreach to medically complex patients through portal messages.

Notably, in every included study, telehealth was already in place in some form and was then adapted or expanded in response to the extreme weather event. For example, an existing patient portal was used to send bulk messages about clinic closures or other disaster-related communications²⁶. An existing direct-to-consumer telehealth platform was advertised to patients in a hurricane-affected area with free sign-up using a hurricane-specific code²¹.

Reported barriers

Several barriers to telehealth implementation were described in reviewed articles. A recurring theme was inequitable access: multiple studies noted patient disparities in video visit utilization by race, ethnicity, age, language proficiency, and a lack of familiarity with telehealth platforms. At the infrastructure level, telehealth's dependence on functional power and telecommunications was noted as a critical vulnerability if these systems fail. Workforce readiness represents a parallel gap when providers are not equipped or trained to deliver care remotely, when support structures do not enable practice from displacement locations, and when regulatory frameworks exclude cross-state licensing that allows surge capacity to be deployed rapidly.

Discussion

In this scoping review, we identified a small but growing body of literature describing the use of telehealth in outpatient healthcare systems during extreme weather events. The findings highlight the important role of telehealth in extreme weather event response and opportunities to strengthen its effectiveness and implementation.

Telehealth's potential in disaster-related health risk reduction depends in part on the vulnerabilities and impacts it is targeting. Extreme weather events pose risks to outpatient care and population health through two pathways: vulnerabilities that increase likelihood of service disruption and impacts when an event occurs. This distinction parallels the disaster risk reduction literature's formulation of risk as a function of hazard probability, vulnerability, exposure (also called impact), and capacity (also called resilience)^{13,14,31}:

$$\text{Risk} = \text{Probability} \times \text{Vulnerability} \times \text{Impact} / \text{Resilience}$$

This review applies that model to the context of outpatient care, creating a framework for understanding contributors to population health risk during extreme weather events and how telehealth interventions might mitigate that risk (Fig. 3).

In mapping the scoping review findings to this framework, we found that telehealth can build resilience by mitigating individual and system-level impacts and by addressing individual-level vulnerabilities. System-level vulnerabilities were rarely identified as addressed through telehealth means, a distribution that may indicate where telehealth is currently being used to reduce risk, and where it is not. More broadly, the framework casts telehealth as a resilience mechanism: a means by which a health system sustains essential care under disruption. How telehealth provides that resilience, whether before, during, or after an event, depends on the capacities that constitute it.

Health system resilience theory further illuminates telehealth's role, describing a resilient system as one able to absorb, adapt to, and transform in response to stressors while sustaining equitable essential functions^{32,33}: absorptive capacity sustains services during an event, adaptive capacity reorganizes delivery with available resources around the event, and transformative capacity restructures care delivery ahead of events to reduce structural vulnerability.

The most consistent finding across this review is that telehealth mitigates health risks posed by extreme weather by enabling health systems to reorganize existing care delivery infrastructure under stress, a pattern consistent with adaptive capacity. Telephone and video visits were shown to maintain chronic disease management for displaced patients; patient portal messaging sustained medication management when physical access was impossible; and direct-to-consumer platforms originally designed for minor acute illness were repurposed to address care otherwise made inaccessible due to road closures, provider displacement, and clinic closures. Critically, the same interventions frequently addressed both vulnerability and impact simultaneously: telephone-based care reduced the baseline susceptibility of rural and geographically isolated patients while also limiting the harm of clinic closures when events occurred, and remote monitoring of medically complex patients reduced structural vulnerability between events while enabling detection of acute deterioration during them. In each case, the technology existed before the event; what changed was its application.

While the evidence documents adaptive redeployment effectively, it reveals an absence of purpose-built disaster telehealth systems, or what health system resilience theory would recognize as transformative capacity. The most sophisticated pre-event investments, including fault-tolerant network design, credentialing of out-of-state providers, and integration of telehealth into routine home care, were built for operational continuity rather than disaster preparedness, making their utility in disasters incidental rather than intentional. The clinical significance of this gap is suggested by one study in which patients with pre-existing telehealth familiarity showed lower post-disaster emergency department and inpatient utilization for ambulatory-care-sensitive conditions than those without prior experience²⁶. This association is hypothesis-generating rather than causal, as telehealth-familiar patients may differ systematically in health status, resources, or technology access, but it is consistent with the possibility that adaptive redeployment performs better when telehealth capacity is built deliberately before events occur. Purpose-built systems structured around proactive enrollment of high-risk populations, pre-designed disaster workflows, and redundant infrastructure represent the most significant unmet need in the literature, and their absence reflects a broader pattern in the literature, where transformative capacity

remains the least operationalized and hardest to measure tier of resilience. Purely reactive (absorptive) deployment was likewise underrepresented: no study documented a health system standing up novel telehealth capacity in real time during an acute event, and the few emergent uses, portal messaging and direct-to-consumer triage, still relied on pre-existing technology.

The evidence across this review has direct implications for how health systems should focus their efforts, which we summarize in Table 3. A common thread runs through them: the value of telehealth for reducing health risk due to extreme weather events is at present incidental rather than intentional. Converting it into durable resilience will require deliberate investment before events occur, including proactive enrollment of high-risk patients, fault-tolerant infrastructure, and regulatory flexibilities made permanent rather than contingent on emergency waivers. These implementation challenges are not evenly distributed; the populations most vulnerable to extreme weather events, including rural communities and medically complex patients, are often the same populations facing the greatest barriers to digital access, making equity-centered design an essential feature of any telehealth resilience strategy.

Table 3
Priorities for practice, policy, and research emerging from this review.

Domain	Recommendation
Practice and policy	
Clinical practice	Proactively enroll patients with chronic illness, geographic isolation, or limited in-person access, and treat telehealth enrollment as disaster preparedness
Infrastructure	Invest in fault-tolerant, cellular-capable telehealth systems
Regulation	Make emergency regulatory flexibilities permanent (cross-state licensure, telephone-visit reimbursement, relaxed prescribing)
Health-system integration	Integrate telehealth into routine care delivery and develop emergency protocols to leverage telehealth in order to maintain access and address urgent needs during extreme weather events
Research	
Study design	Advance beyond descriptive, event-specific reports to systematic evaluation of telehealth as a component of disaster preparedness
Population targeting	Map extreme weather probabilities against population vulnerabilities and potential impacts to identify and target high-risk groups
Outcomes	Evaluate patient health outcomes, not only health-system or telehealth utilization metrics
Scalability and Equity	Study how telehealth platforms can be scaled rapidly and equitably during emergencies

Several considerations temper these findings. The included studies were heterogeneous in design and setting, limiting the ability to directly compare findings across studies, and offered limited data on

patient health outcomes. The review may also be subject to publication bias: studies describing successful telehealth implementation during disasters may be more likely to be published than those reporting implementation challenges or unsuccessful programs, potentially yielding an overly optimistic view of telehealth's role and associated outcomes. In addition, because inclusion required a documented telehealth component, this review characterizes how telehealth was used rather than how often it was available, declined, or proved ineffective, and therefore cannot establish telehealth's comparative effectiveness. Together, these constraints highlight the need for more rigorous and geographically diverse research evaluating telehealth implementation and outcomes during extreme weather events.

Taken together, care disruptions due to extreme weather can exacerbate health risks for vulnerable populations, and telehealth is a promising strategy to maintain access. Future research should explore the effectiveness of telehealth interventions in addressing chronic and acute health needs during extreme events, particularly for patients with complex medical and social circumstances. Aligning telehealth strategies with the specific risks they address may strengthen health system resilience to future extreme weather events.

Methods

Protocol

The scoping review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines³⁴, with an a priori protocol defining Population-Concept-Context eligibility criteria, search terms, and analytic approach (Supplementary Appendix).

Eligibility criteria

We included peer-reviewed studies describing the implementation or evaluation of telehealth or remote care during extreme weather events in outpatient or ambulatory settings. Extreme weather exposures included hurricanes, floods, wildfires, winter storms, and extreme heat. Studies were excluded if they lacked a telehealth component, were unrelated to extreme weather, or focused solely on inpatient or emergency settings. Non-English publications and conference abstracts were excluded.

Search strategy

We searched PubMed/MEDLINE, Embase, and Cochrane Libraries from January 2000 through July 2025, using controlled vocabulary and keywords related to telehealth and extreme weather, and screened reference lists of included articles. Records were imported into Covidence systematic review software and deduplicated.

Screening and data charting

All titles and abstracts underwent dual independent screening by three reviewers (VM, SC, and DZ), and full texts underwent dual independent review by two reviewers (VM and SC); disagreements were

resolved by discussion. Consistent with PRISMA-ScR guidance for scoping reviews, we did not perform a formal critical appraisal of methodological quality or risk of bias.

The review's domains were specified a priori: data extraction followed a structured charting form, developed a priori and piloted on five included studies, that captured study characteristics, weather event type, telehealth modality, implementation context, and system- and patient-level vulnerabilities and impacts, organized within a disaster-risk framework ($\text{Risk} = [\text{Probability} \times \text{Vulnerability} \times \text{Impact}] / \text{Resilience}$) adapted from the disaster-risk-reduction and health-system-resilience literatures. All included studies were charted in a dual independent review by two reviewers (VM and SC).

Data synthesis

Within these *a priori* domains, the specific subcategories of telehealth strategies, vulnerabilities, and impacts were derived inductively from the included studies, with AI assistance, and refined by the study team (see Supplementary Appendix).

A large language model (Claude, Anthropic; version Opus 4.6) was used to assist inductive coding of the charted data. All outputs were reviewed and adjudicated by the study team. Full details of its role, the prompts used, and quality-control procedures are provided in the Supplementary Appendix.

Declarations

Data Availability

All data supporting the findings of this study are available within the article and its supplementary information. The full study-level extraction and the telehealth–vulnerability/impact pairing dataset are provided as Supplementary Table 1 and Supplementary Table 2. The review analyzed only data extracted from previously published studies; no new individual-participant data were generated.

Code Availability

No custom code or software was generated for this study.

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Author Contributions

Dr. McDonald had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Concept and design:* McDonald, Zulman, Ferguson, Schuttner. *Acquisition, analysis, or interpretation of data:* All authors. *Drafting of the manuscript:* McDonald. *Critical revision of the manuscript for important intellectual content:* All authors. *Administrative, technical, or material support:* McDonald, Zulman. *Supervision:* Zulman.

Competing Interests

Dr McDonald reported no disclosures. Dr Castro reported no disclosures. Dr Ferguson reported no disclosures. Dr Schuttner reported no disclosures. Dr Zulman reported no disclosures. No other disclosures were reported.

Ethics Statement

This scoping review analyzed only data from previously published studies and did not involve human participants or access to identifiable individual-level data; institutional review board approval and informed consent were therefore not required.

References

1. Seneviratne, S. I. *et al.* 2021: Weather and Climate Extreme Events in a Changing Climate. in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. Masson-Delmotte et al.) 1513–1766 (Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA). doi:10.1017/9781009157896.013.
2. Valente, M. *et al.* The impacts of extreme weather events on health services and systems: A systematic review of reviews. *Public Heal.* **250**, 106049 (2026).
3. Salas, R. N. *et al.* Impact of extreme weather events on healthcare utilization and mortality in the United States. *Nat. Med.* **30**, 1118–1126 (2023).
4. Kazi, D. S. *et al.* Climate Change and Cardiovascular Health. *JAMA Cardiol.* **9**, 748–757 (2024).
5. Dewi, S. P., Kasim, R., Sutarsa, I. N. & Dykgraaf, S. H. A scoping review of the impact of extreme weather events on health outcomes and healthcare utilization in rural and remote areas. *BMC Heal. Serv. Res.* **24**, 1333 (2024).

6. Carrel, M. et al. Health Care Utilization Among Texas Veterans Health Administration Enrollees Before and After Hurricane Harvey, 2016-2018. *JAMA Netw. Open* **4**, e2138535 (2021).
7. Wu, Y. et al. Climate Change, Floods, and Human Health. *N. Engl. J. Med.* **391**, 1949–1958 (2024).
8. Bell, M. L., Gasparrini, A. & Benjamin, G. C. Climate Change, Extreme Heat, and Health. *N. Engl. J. Med.* **390**, 1793–1801 (2024).
9. Dzau, V. J., Laitner, M. H., Balatbat, C. A. & Taylor, S. Climate Change and Human Health — A Research Agenda for Action. *N. Engl. J. Med.* **393**, 88–92 (2025).
10. Panah, H. R., Madanian, S. & Yu, J. Integrating Smart Health Solutions in Disaster Preparedness Strategies. *Stud. Heal. Technol. Inform.* **330**, 173–192 (2025).
11. Madanian, S., Norris, T. & Parry, D. Disaster eHealth: Scoping Review. *J. Méd. Internet Res.* **22**, e18310 (2020).
12. Chen, A. et al. Telehealth Policy, Practice, and Education: a Position Statement of the Society of General Internal Medicine. *J. Gen. Intern. Med.* **38**, 2613–2620 (2023).
13. Blaikie, P., Cannon, T., Davis, I. & Wisner, B. *At Risk: Natural Hazards, People's Vulnerability and Disasters*. (New York: Routledge., 1994).
14. Hammer, C. C., Brainard, J., Innes, A. & Hunter, P. R. (Re-) conceptualising vulnerability as a part of risk in global health emergency response: updating the pressure and release model for global health emergencies. *Emerg. Themes Epidemiology* **16**, 2 (2019).
15. Parks, R. M. et al. Association of Tropical Cyclones With County-Level Mortality in the US. *JAMA* **327**, 946–955 (2022).
16. Romanello, M. et al. The 2024 report of the Lancet Countdown on health and climate change: facing record-breaking threats from delayed action. *Lancet* **404**, 1847–1896 (2024).
17. Lokmic-Tomkins, Z. et al. Lessons Learned from Natural Disasters around Digital Health Technologies and Delivering Quality Healthcare. *Int. J. Environ. Res. Public Heal.* **20**, 4542 (2023).
18. Vo, A. H., Brooks, G. B., Bourdeau, M., Farr, R. & Raimier, B. G. University of Texas Medical Branch Telemedicine Disaster Response and Recovery: Lessons Learned from Hurricane Ike. *Telemed. e-Heal.* **16**, 627–633 (2010).
19. Radcliff, T. A., Chu, K., Der-Martirosian, C. & Dobalian, A. A Model for Measuring Ambulatory Access to Care Recovery after Disasters. *J. Am. Board Fam. Med.* **31**, 252–259 (2018).
20. Uscher-Pines, L., Fischer, S. & Chari, R. The Promise of Direct-to-Consumer Telehealth for Disaster Response and Recovery. *Prehospital Disaster Med.* **31**, 454–456 (2018).
21. Der-Martirosian, C., Griffin, A. R., Chu, K. & Dobalian, A. Telehealth at the US Department of Veterans Affairs after Hurricane Sandy. *J. Telemed. Telecare* **25**, 310–317 (2019).
22. Der-Martirosian, C., Heyworth, L., Chu, K., Mudoh, Y. & Dobalian, A. Patient Characteristics of VA Telehealth Users During Hurricane Harvey. *J. Prim. Care Community Heal.* **11**, 2150132720931715 (2020).

23. Der-Martirosian, C., Chu, K. & Dobalian, A. Use of Telehealth to Improve Access to Care at the United States Department of Veterans Affairs During the 2017 Atlantic Hurricane Season. *Disaster Med. Public Heal. Prep.* **17**, e6 (2020).
24. Grover, J. M. et al. Novel Use of Telemedicine by Hurricane Evacuation Shelters. *Prehospital Emerg. Care* **24**, 804–812 (2020).
25. Baek, J. et al. Assessing Patient Needs During Natural Disasters: Mixed Methods Analysis of Portal Messages Sent During Hurricane Harvey. *J. Méd. Internet Res.* **23**, e31264 (2021).
26. Friedman, R. S. C., Carpenter, D. M., Shaver, J. M., McDermott, S. C. & Voelkel, J. Telemedicine Familiarity and Post-Disaster Utilization of Emergency and Hospital Services for Ambulatory Care Sensitive Conditions. *Am. J. Prev. Med.* **63**, e1–e9 (2022).
27. Khairat, S., Zebrowski, A., Kwong, E., Edson, B. & Gianforcaro, R. Changes in Patient Characteristics in Telehealth Usage During Times of Crisis. *Stud. Heal. Technol. Inform.* **294**, 905–909 (2022).
28. Miyatake, H. et al. The Impact of Heavy Snowfall on Home Care: A 2018 Case Study in Fukui City, Japan. *Disaster Med. Public Heal. Prep.* **16**, 468–472 (2020).
29. Casey, J. A. et al. The 2025 Los Angeles Wildfires and Outpatient Acute Health Care Utilization. *JAMA Heal. Forum* **6**, e254632 (2025).
30. Ramachandran, A., Northcraft, H., Steers, W. N. & Der-Martirosian, C. Telehealth Utilization for Primary Care Delivery During Hurricanes Michael (2018) and Ian (2022) in the Veterans Health Administration. *Telemed. e-Heal.* **31**, 866–874 (2025).
31. United Nations Office for Disaster Risk Reduction (UNDRR). Sendai Framework Terminology on Disaster Risk Reduction. *Disaster Risk* <https://www.undrr.org/terminology/disaster-risk> (2017).
32. Blanchet, K., Nam, S. L., Ramalingam, B. & Pozo-Martin, F. Governance and Capacity to Manage Resilience of Health Systems: Towards a New Conceptual Framework. *Int. J. Heal. Polic. Manag.* **6**, 431–435 (2017).
33. Witter, S. et al. Health system resilience: a critical review and reconceptualisation. *Lancet Glob. Heal.* **11**, e1454–e1458 (2023).
34. Tricco, A. C. et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann. Intern. Med.* **169**, 467–473 (2018).

Figures

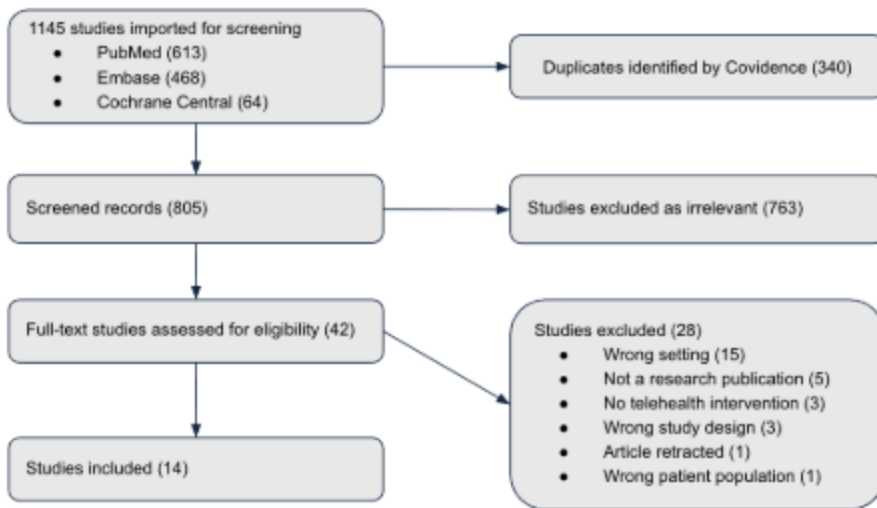


Figure 1

PRISMA 2020 flow diagram for scoping review of telehealth use in extreme weather events

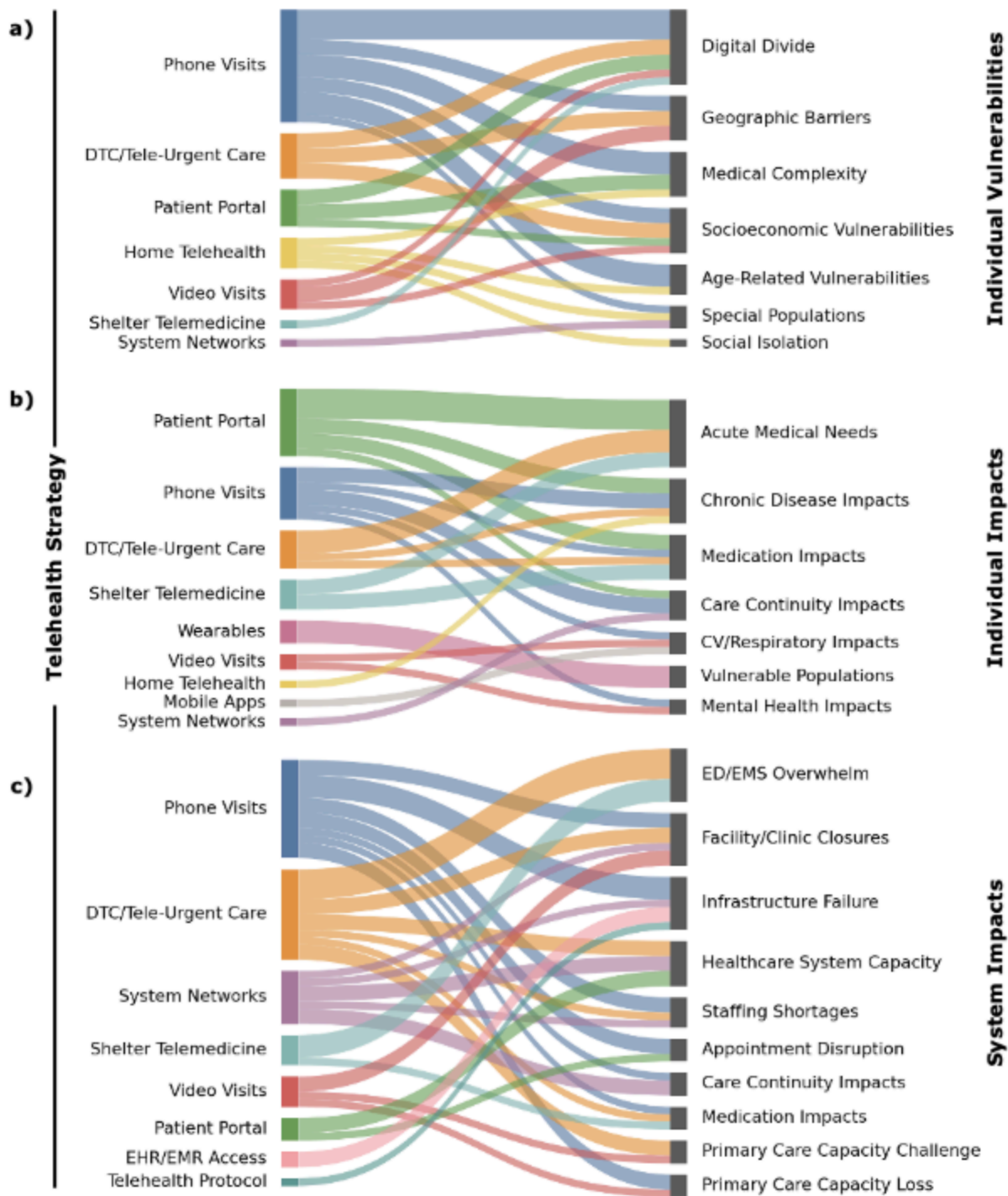


Figure 2

Telehealth strategies found to be paired with (a) individual patient vulnerabilities, (b) individual patient impacts, and (c) healthcare system impacts. Line thickness is proportional to the number of pairings found.

$$\text{Risk} = (\text{Probability} \times \text{Vulnerability} \times \text{Impact}) / \text{Resilience}$$

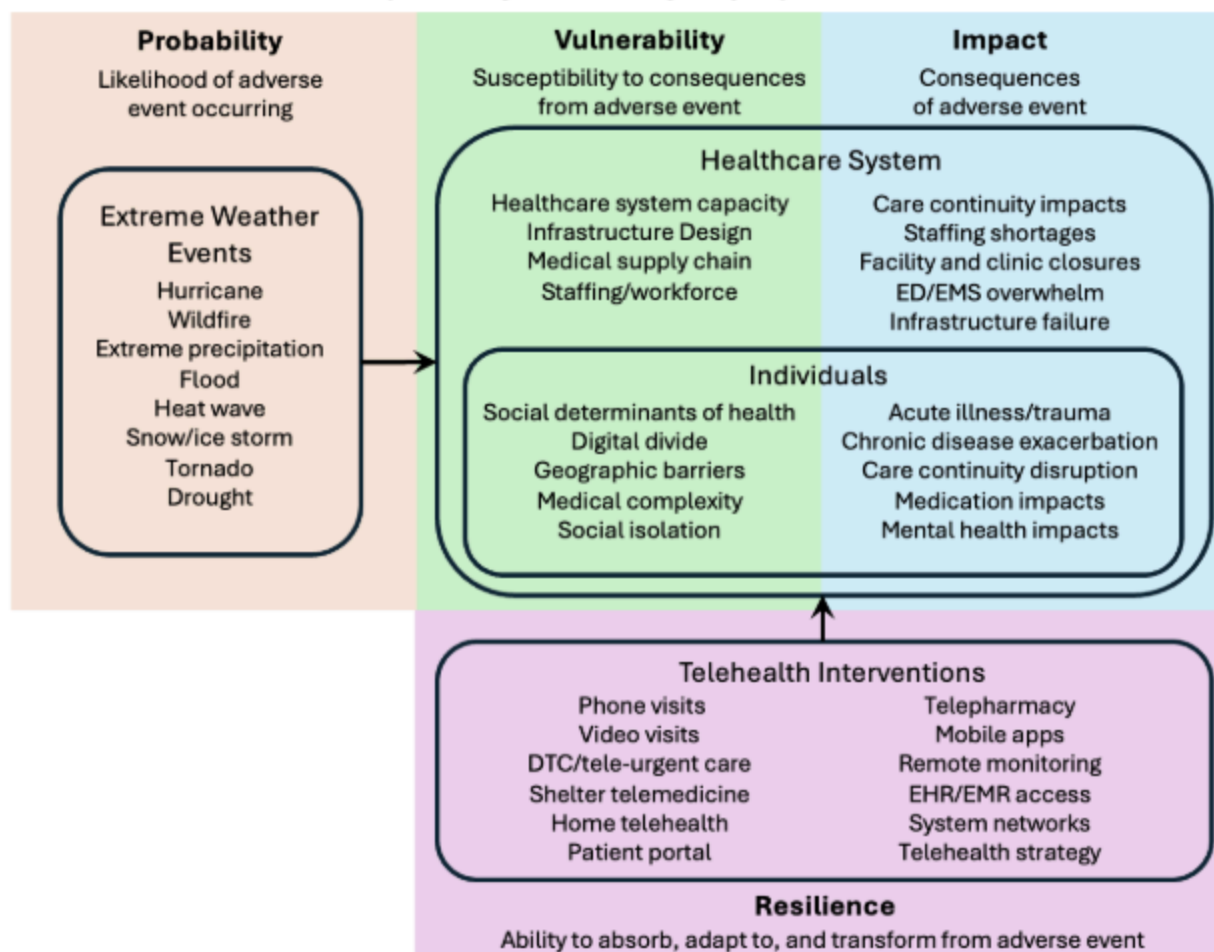


Figure 3

Framework for telehealth as a resilience mechanism to reduce health risks in extreme weather events.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Supplementaryappendix.docx](#)
- [SupplementaryTable2.csv](#)
- [SupplementaryTable1.csv](#)